OPERATION MANUAL

MODEL 320

Vibration Selection

REVISED

. . . SERIAL NO. PREFIX "E" AND ON . . .

OPERATION MANUAL
MODEL 320
Vibration Selection

REVISED

. . . SERIAL NO. PREFIX "E" AND ON . . .

Level = 3%

Freq = 5%

pickup (544) = 8%

IRD MECHANALYSIS, INC.
SUBSIDIARY OF H. H. ROBERTSON COMPANY

6150 HUNTLEY RD. COLUMBUS, OHIO 43229
PHONE: 614/885-5376 CABLE ADDRESS: IRDMECH, USA

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INTRODUCTION

Conditions in a machine that eventually result in breakdown and extensive repairs can be detected by the vibration they cause. An increase in the severity of such mechanical troubles is revealed by increased vibration. These vibrations are often complex and require a vibration meter with the ability to select individual vibrations from the others. This is the job for which the Vibration Selector is provided.

This manual is written to provide you with an understanding of how the instrument is operated as well as its application in many areas of your plant.

There are two versions of this instrument: the 320 which provides vibration measurements in English units (inches) and the 320M which provides vibration measurements in metric units (microns & millimeters/seconds).

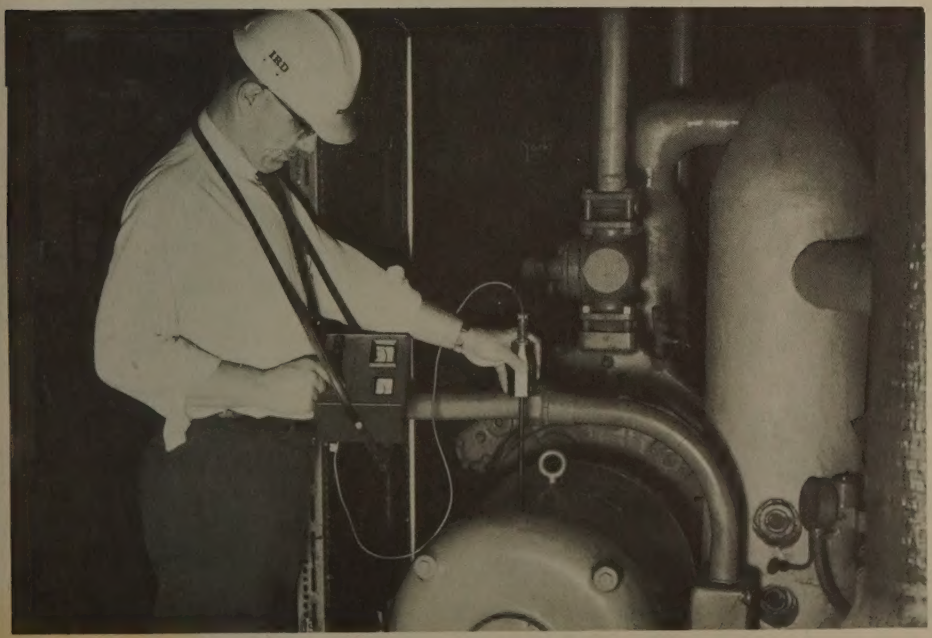


Figure 1. Model 320 Vibration Selector

DESCRIPTION

The battery-operated IRD Model 320 Vibration Selector uses the latest proven solid state circuitry to provide accurate vibration measurement over the range of 300 to 600,000 CPM (filter out) and analysis over the range of 500 to 50,000 CPM (filter in).

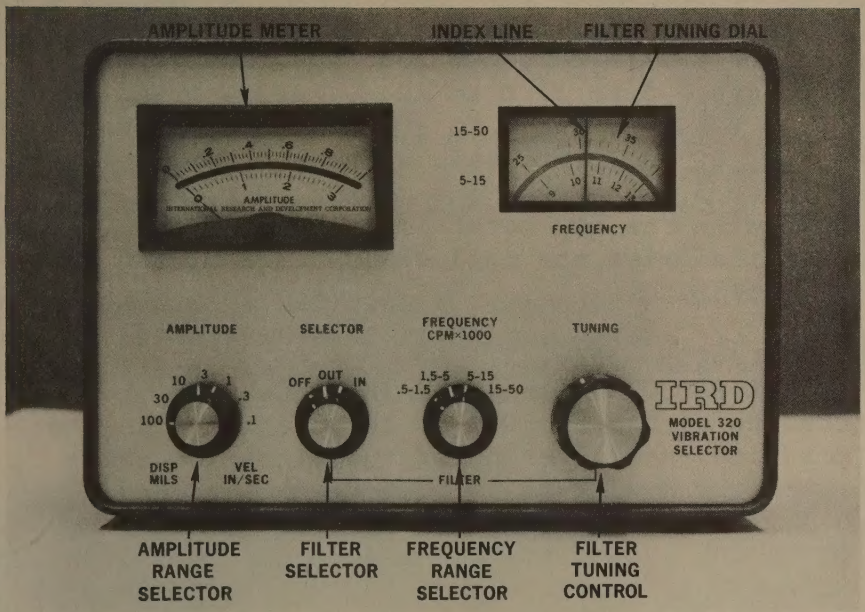
The front panel (see Figure 2) is arranged according to function for convenience of operation. The left side of the panel contains the AMPLITUDE METER and the associated AMPLITUDE RANGE SELECTOR. The right side of the panel contains the FILTER SELECTOR and the associated FREQUENCY RANGE SELECTOR and FILTER TUNING DIAL and CONTROL.

The rear panel (see Figure 3) contains the VIBRATION PICKUP INPUT CONNECTOR, BATTERY TEST SWITCH, and DISPLACEMENT-VELOCITY SELECTOR. A QUARTER TURN DOOR LATCH provides easy access to the battery compartment.

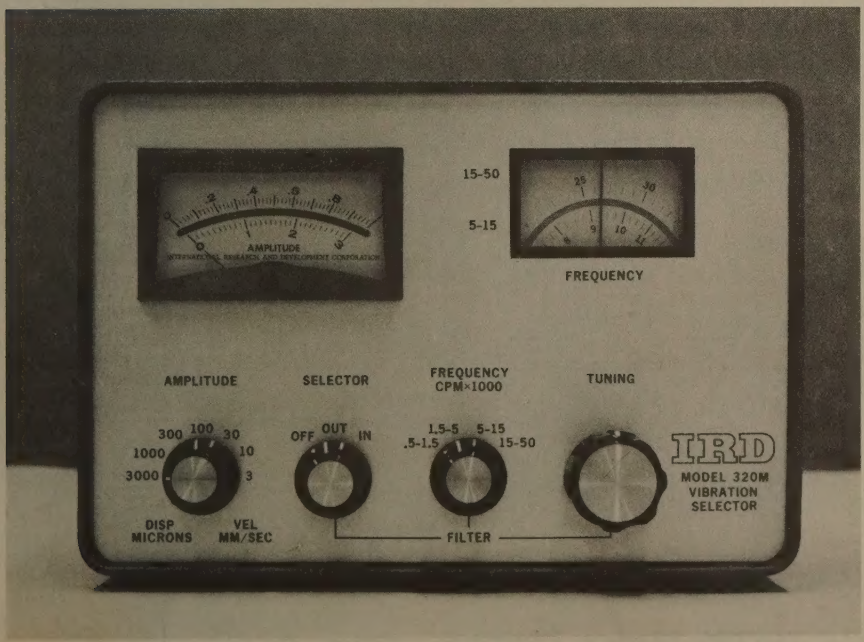
On each side of the vinyl-covered aluminum case is a CARRYING STRAP STUD.

AMPLITUDE METER (Fig. 2)
The AMPLITUDE METER indicates the peak-to-peak Displacement or peak Velocity of vibration. The METER has two scales, 0 to 1.0 and 0 to 3.0. The scale used to read the vibration amplitude is determined by the position of the AMPLITUDE RANGE SELECTOR.

AMPLITUDE RANGE SELECTOR (Fig. 2)
The AMPLITUDE RANGE SELECTOR determines the full-scale meter range. In English units, full-scale amplitudes from .1 to 100 (mils or inches per second) are covered in seven ranges - 0 to .1, 0 to .3, 0 to 1.0, 0 to 3.0, 0 to 10.0, 0 to 30.0, and 0 to 100.0. Positions marked 100, 10, 1 and .1 are used with the top meter scale (0 to 1). Positions marked 30, 3 and .3 are used with the bottom meter scale (0 to 3). Each position indicates the full-scale range of the meter for that setting.



English Units



Metric Units

Figure 2. Front Panel

In Metric units, full-scale amplitudes from 3 to 3000 (microns or millimeters per second) are covered in seven ranges - 0 to 3, 0 to 10, 0 to 30, 0 to 100, 0 to 300, 0 to 1000, and 0 to 3000. Positions marked 3000, 300, 30 and 3 are used with the bottom meter scale (0 to 3.0). Positions marked 1000, 100 and 10 are used with the top meter scale (0 to 1.0). Each position indicates the full scale range of the meter for that setting.

FILTER SELECTOR (Fig. 2)
The FILTER SELECTOR turns the instrument on when switched to either the OUT or IN position. In the OUT position, no filtering of the vibration takes place and the amplitude indicated on the meter is the overall vibration present over the frequency range of 300 CPM to 600,000 CPM. To measure the amplitude of vibration at a single frequency, the FILTER SELECTOR is switched to the IN position. The amplitude (Displacement or Velocity) indicated on the meter is for the frequency to which the Filter is tuned.

FREQUENCY RANGE SELECTOR (Fig. 2)
The frequency range of the Filter is determined by the position of the FREQUENCY RANGE SELECTOR. There are four positions: .5 - 1.5; 1.5 - 5; 5 - 15; 15 - 50. The respective filter range for each position is determined by multiplying the position markings by 1000 as indicated on the panel. The respective ranges are:

FREQUENCY RANGE SELECTOR POSITION	FREQUENCY RANGE
.5 - 1.5	500 to 1500 CPM
1.5 - 5	1500 to 5000 CPM
5 - 15	5000 to 15000 CPM
15 - 50	15000 to 50000 CPM

FILTER TUNING DIAL & CONTROL (Fig. 2)
The FILTER TUNING CONTROL tunes the instrument filter to any desired vibration frequency over the frequency

range of 500 to 50,000 CPM. The frequency to which the Filter is tuned is indicated under the INDEX LINE on the DIAL. The DIAL has two scale ranges, 5 - 15 (bottom scale) and 15 - 50 (top scale). The bottom scale, 5 - 15, is used for Frequency Range Selector positions of .5 - 1.5 and 5 - 15. The top scale, 15 - 50, is used for Frequency Range Selector positions of 1.5 - 5 and 15 - 50.

VIBRATION PICKUP RECEPTACLE (Fig. 3)
The VIBRATION PICKUP RECEPTACLE receives the connector on the pickup cable from the vibration pickup.

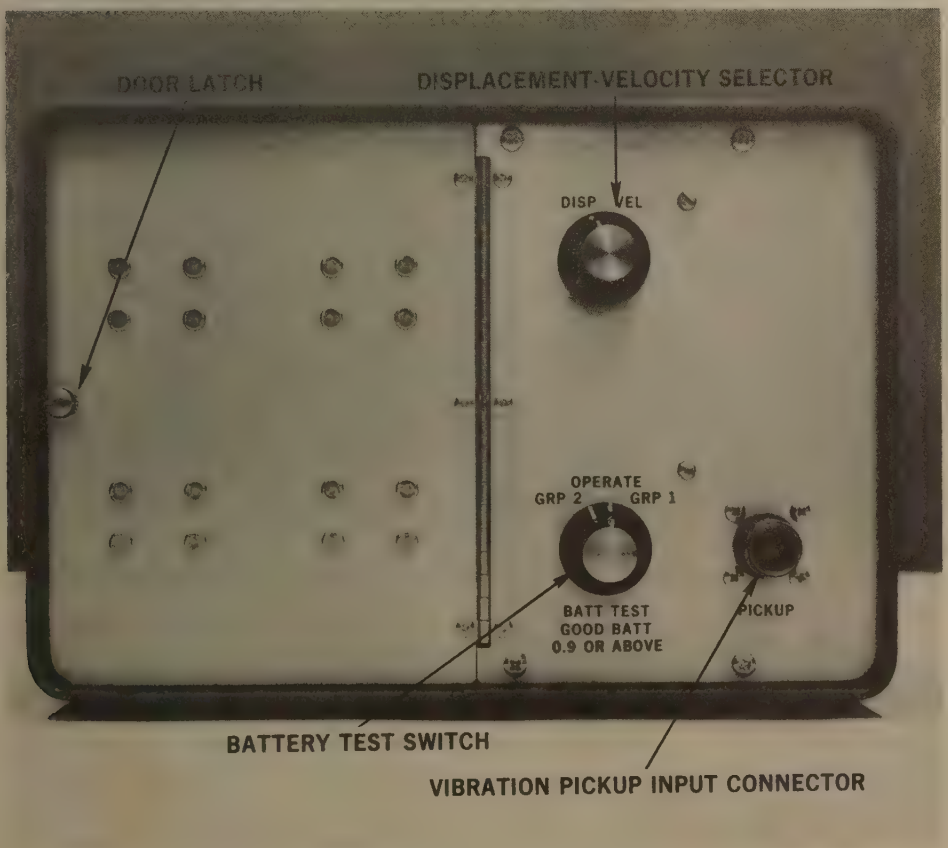


Figure 3. Rear Panel

DISPLACEMENT-VELOCITY SELECTOR (Fig. 3)
Either the Displacement or Velocity of the vibration may be chosen for measurement. Displacement is indicated on the Meter in Mils (1 mil = .001 inch). Velocity is indicated in inches per second. For the 320M Displacement is indicated on the meter in microns and Velocity is indicated in millimeters per second.

BATTERY TEST SWITCH (Fig. 3)
The BATTERY TEST SWITCH is provided to check both groups of batteries used to operate the instrument. The switch is spring loaded to return to the center or OPERATE position.

QUARTER TURN DOOR LATCH (Fig. 3)
The battery compartment opens with a QUARTER TURN of the DOOR LATCH.

CARRYING CASE - IRD Part #3489 (Fig. 4)
The 8" x 6-1/2" x 13-1/2" CARRYING CASE has storage provisions for the instrument and all its accessories.

IRD MODEL 544 VIBRATION PICKUP (Fig. 4)
The VIBRATION PICKUP senses vibration and translates it into an electrical signal proportional to the velocity of the vibration. It may be hand held or mounted in any position without effecting sensitivity or accuracy. It is sensitive to vibrations only along its long axis. A 1/4"-28NF x 1/4" tapped hole is provided for attaching the STRAIGHT PROBE or mounting permanently to a machine. It will withstand temperatures from -40° to 500° F.

STRAIGHT PROBE - IRD Part #1103 (Fig. 4)
The STRAIGHT PROBE is provided to reach out of the way places and is screwed into the end of the VIBRATION PICKUP with the 1/4"-28NF x 3/16" stud. It does not affect the operation of the pickup.

Figure 4. Model 320 Standard Accessories
A - Carrying Case
B - Model 544 Vibration Pickup
C - Straight Probe
D - 4' Pickup Cable
E - Carrying Strap

4' PICKUP CABLE - IRD Part #2482 (Fig. 4)
The PICKUP CABLE connects the VIBRATION PICKUP to the INPUT RECEPTACLE of the instrument. Belden #8401 cable and MS3106A-10SL-4S Amphenol connectors are used.

CARRYING STRAP - IRD Part #3829 (Fig. 4)
The CARRYING STRAP attaches to the STUDS on the sides of the instrument case and is normally placed around the neck to position the instrument for operation as shown in Figure 1.

SPECIFICATIONS

Frequency Range
300 to 600,000 CPM

Filter Frequency Range
500 to 50,000 CPM in four ranges:
500 to 1500; 1500 to 5000; 5000 to 15,000; 15,000 to 50,000 CPM

Filter Selectivity
Bandwidth 10% Max of selected frequency at 3 db down points

Sensitivity (English Units)
.005 mils (.000 005") peak-to-peak displacement
.005 inch/second peak velocity

Sensitivity (Metric Units)
.15 microns peak-to-peak displacement
.15 millimeter/second peak velocity

Displacement Range (English Units)
0 to 100 mils peak-to-peak in 7 overlapping ranges:
0 to .1; 0 to .3; 0 to 1; 0 to 3; 0 to 10; 0 to 30; 0 to 100 mils (1 mil = .001")

Displacement Range (Metric Units)
0 to 3000 microns peak-to-peak in 7 overlapping ranges: 0 to 3; 0 to 10; 0 to 30; 0 to 100; 0 to 300; 0 to 1000; 0 to 3000 microns.

Velocity Range (English Units)
0 to 100 inches/second peak in 7 overlapping ranges:
0 to .1; 0 to .3; 0 to 1; 0 to 3; 0 to 10; 0 to 30; 0 to 100 inches/second

Velocity Range (Metric Units)
0 to 3000 millimeters/second in 7 overlapping ranges: 0 to 3; 0 to 10; 0 to 30; 0 to 100; 0 to 300; 0 to 1000; 0 to 3000 millimeters/second.

Overall Dimensions

Instrument - 4" x 6-5/8" x 10"

Carrying Case - 8" x 6-1/2" x 13-1/2"

Weight

Instrument with batteries - 4-1/2 pounds

Instrument with carrying case and accessories - 9-1/2 pounds

Shipping Weight - 14 pounds

Power Requirements

Four (4) 8.1 volt mercury batteries - Mallory TR-136R, Burgess H136R, or Eveready E136N. Group 1 battery life 750 hours; Group 2 battery life 250 hours for normal intermittent operation.

To prepare the 320 Vibration Selector for operation, proceed as follows:

1. Screw the straight probe into the Model 544 Vibration Pickup.
2. Connect one end of the pickup cable to the pickup and the other to the pickup input receptacle.
3. Test the batteries. Turn the Filter Selector switch to the OUT position. This turns the instrument on. Displacement-Velocity Selector may be in either position. Turn the Battery Test switch to the Group 1 position. Good batteries read .9 or above on the 0 to 1 scale of the Amplitude Meter. Turn to Group 2 position. Good batteries read .9 or above on the 0 to 1 scale.
4. Attach the Carrying Strap to the Studs provided on the sides of the instrument case. The usual carrying position puts the bottom of the instrument against the stomach as it hangs from the strap about the neck. (See Figure 1.) This frees one hand for holding the pickup. The other hand operates the switches on the instrument.

Vibration Measurement

The purpose of the Vibration Selector is to measure machinery vibration for comparison with vibration standards. When the vibration shows an increase or exceeds allowable limits then trouble is present. Since vibration is usually the result of troubles such as unbalance, misalignment, looseness, bad bearings; the logical place on a machine for measurement is the bearings of the machine.

To measure vibration prepare the instrument as previously outlined.

1. Turn the Filter Selector to the OUT position.
2. Place the vibration pickup on a bearing housing of the machine in either the vertical, horizontal or axial position. The pickup should be held firmly against the point of measurement with only enough pressure to prevent the straight probe from chattering. Hold the pickup perpendicular to the shaft of the machine. (Axial measurements are taken with the long axis of the pickup on the bearing housing parallel to the shaft centerline.)
3. Starting at the least sensitive full scale range, turn the Amplitude Range Selector clockwise to each position until a reading of at least 1/3 full scale is obtained on the Amplitude Meter. This reading is the overall vibration at the point where the pickup is applied.

The meter has two sets of graduations or scales - the top scale, from 0 to 1; the bottom scale, from 0 to 3. The setting of the Amplitude Range Selector determines which scale applies. If the setting is 100, 10, 1 or .1, use the top scale when reading the meter, placing the decimal point as indicated by the Amplitude Range. Thus on the 100 setting, full scale on the meter becomes 100 mils or 100 inches/second, .6 on the meter becomes 60 mils. If the Amplitude Range Selector is set on 30, 3 or .3 use the bottom scale, placing the decimal point in the same way. The indications are in mils displacement or inches/second velocity depending on the position of the Displacement Velocity Selector.

The preceding paragraph applies to the 320 (English Units) and the 320M (Metric Units) in the same way except the full scale meter ranges as selected by the Amplitude Range Selector are in microns or millimeters/second depending on the position of the Displacement Velocity Selector.

Vibration measurements taken this way, i.e., with the Filter "OUT" are overall vibration readings or the vector sum of all the vibrations at the point the

pickup is applied. Overall vibration readings are used for comparison with previous readings to detect an increase that may mean trouble is present or for comparison with previously established standards. To learn what is causing the vibration it is necessary to use the Filter.

Vibration Analysis

Normally, machinery vibration occurs at frequencies equal to 1, 2, 3, 4 and sometimes higher multiples of the rotating speed of a part. Therefore, a check of the machine nameplate speeds will help determine at which frequencies vibration is likely to occur. By tuning the filter to these frequencies, the presence of any vibration is determined.

The tunable filter works in much the same way as a radio in that it is tuned to one frequency of vibration while rejecting the others. To tune the filter:

1. Switch the Filter Selector to the IN position.
2. Switch the Frequency Range Selector to the range which includes the frequency equal to the machine's speed. (Example: Machine speed 1800 RPM - Range is 1.5 - 5 or 1500 to 5000 CPM.)
3. Turn the Filter Tuning Dial until the approximate frequency on the dial is under the index line. Adjust the Amplitude Range for a meter indication of at least one-third full scale.
4. Adjust the Tuning Dial from side to side until the highest reading on the meter is obtained. Change the Amplitude Range as required to keep the reading in the top two-thirds of the meter.
5. Read the amount indicated on the meter. Read the frequency under the Index.
6. The Filter may be tuned to each vibration present in the same manner. The Filter may also be used to "scan" through the entire frequency range just as you might search a radio tuning dial for unknown stations. Scan the filter slowly to allow the instrument time to react. At the

same time adjust the Amplitude Range for an up scale indication on the Amplitude Meter.

Velocity Measurement

The two basic operations just described, Vibration Measurement and Analysis, result in accurate readings of either vibration DISPLACEMENT or VELOCITY. Displacement is a measure of how far the vibrating part moves. Velocity is a measure of how fast the vibrating part is moving. Both are a measure of how much vibration is present. Because velocity is a function of both displacement and frequency, it provides an apparent added sensitivity to high frequency vibrations.

For instance, a vibration displacement of .1 mil (2.54 microns) results in the same meter reading when the frequency is 1800 CPM as it does at 18,000 CPM. The velocity for .1 mil at 1800 CPM is .0094 in/sec (.239 mm/sec) but at 18,000 CPM the velocity is ten times as large or .094 in/sec (2.39 mm/sec). This means that small vibrations occurring at high frequency are easier to detect if velocity measurements are used. Since troubles such as bad bearings and gears cause vibration at high frequency, velocity measurements are extremely valuable.

TABLE I

English to Metric System Conversion

1 mil = .001 inch = 25.4 microns

1 inch/second = 25.4 millimeters/second

Preventive Maintenance

The most popular application of the Vibration Selector is making periodic vibration checks for preventive maintenance purposes. Many companies rely on the detection of a vibration increase as an early symptom of wear or mechanical trouble. By detecting the condition early, repairs can be scheduled at a convenient time. Thus maintenance costs and downtime are reduced and product spoilage minimized. Recommendations for a Preventive Maintenance Program based on vibration as the key to machinery conditions are available from IRD without obligation.

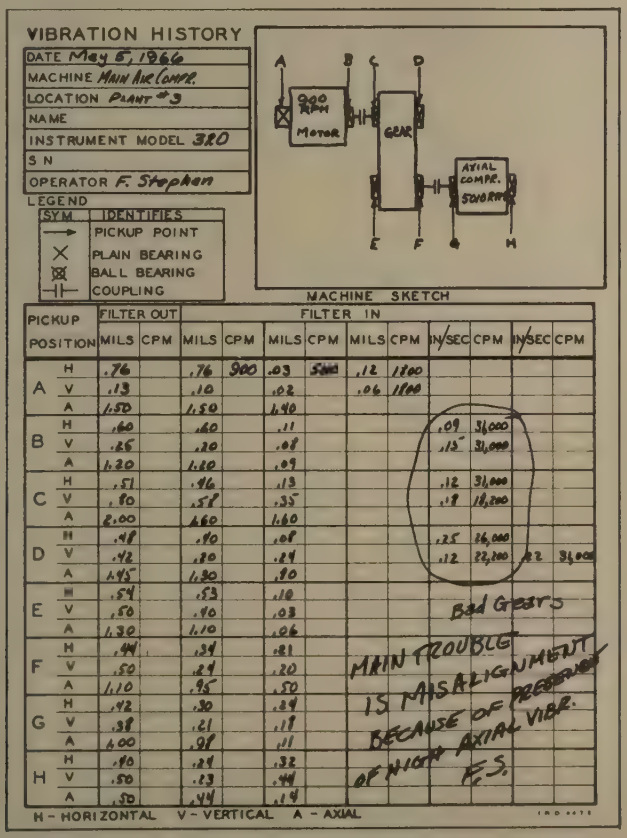


Figure 5. Vibration History Form

When trouble is detected by an increase in machine vibration it is helpful to be able to identify what is wrong. This is done by analyzing the vibration at each bearing housing of the machine. Figure 5 shows a form used to record the vibration data.

1. Sketch the machine to show each bearing or pickup point in relation to the major rotating parts of the machine. The sketch shown is typical of the essential items.
2. Measure and record the vibration at each pickup point in the horizontal, vertical and axial directions with the Filter OUT. Then analyze the vibration at each point recording the amplitude (Displacement or Velocity) for each frequency present.
3. The type of trouble is identified by comparing the data with the known characteristics of vibration for various causes as listed in the Vibration Identification Chart in Figure 6.

VIBRATION IDENTIFICATION WITH A MODEL 320

CAUSE	AMPLITUDE	FREQUENCY	REMARKS
Unbalance	Proportional to unbalance. Largest in radial direction.	1 x RPM	Most common cause of vibration.
Misalignment couplings or bearings and bent shaft	Large in axial direction 50% or more of radial vibration	1 x RPM usual 2 & 3 x RPM sometimes	Best found by appearance of large axial vibration. Use dial indicators or other method for positive diagnosis.
Bad bearings anti-friction type	Unsteady - use velocity measurement if possible	Very high several times RPM	Bearing responsible most likely the one nearest point of largest high-frequency vibration.
Eccentric journals	Usually not large	1 x RPM	If on gears largest vibration in line with gear centers. If on motor or generator vibration disappears when power is turned off.
Bad gears or gear noise	Low - use velocity measure if possible	Very high gear teeth times RPM	
Mechanical looseness		2 x RPM	Usually accompanied by unbalance and/or misalignment.
Bad drive belts	Erratic or pulsing	1, 2, 3 & 4 x RPM of belts	
Electrical	Disappears when power is turned off.	1 x RPM or 1 or 2 x synchronous frequency.	If vibration amplitude drops off instantly when power is turned off cause is electrical.
Aerodynamic hydraulic		1 x RPM or number of blades on fan or impeller x RPM	Rare as a cause of trouble except in cases of resonance.
Reciprocating forces		1, 2 & higher orders x RPM	Inherent in reciprocating machines can only be reduced by design changes or isolation.

IRD #393-1

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Figure 6. Vibration Identification Chart

4. Figures 7 and 8 provide guides for determining if a vibration is excessive and requires correction. Figure 7 is for Machine Tools and Figure 8 is for all other general type machines.

TENTATIVE GUIDE TO VIBRATION TOLERANCES FOR MACHINE TOOLS

TYPE OF MACHINE	Displacement of vibrations as read with pickup on spindle bearing housing in the direction of cut.
	Tolerance Range
Grinders	
Thread Grinder	.01 – .06 mils
Profile or Contour Grinder	.03 – .08 mils
Cylindrical Grinder	.03 – .10 mils
Surface Grinder (vertical reading)	.03 – .2 mils
Gardner or Body Type	.05 – .2 mils
Centerless	.04 – .1 mil
Boring Machine	.06 – .1 mil
Lathe	.2 – 1.0 mils

These values come from the experience of IRD personnel who have been troubleshooting machine tools for over 10 years with the IRD equipment. They *merely indicate the range in which satisfactory parts* have been produced and will vary depending upon size and finish tolerances.

IRD #192

Figure 7. Guide to Machine Tool Tolerances

Incoming Inspection

Vibration tolerances are often included in specifications of purchased components to prevent excess vibration in finished products. The 320 Vibration Selector is ideal for inspection in receiving or on the assembly line.

Field Service

Field engineers and service men can quickly determine if vibration is the justifiable cause of a customer complaint. The instrument avoids the expense of more costly equipment and is easily carried to the job.

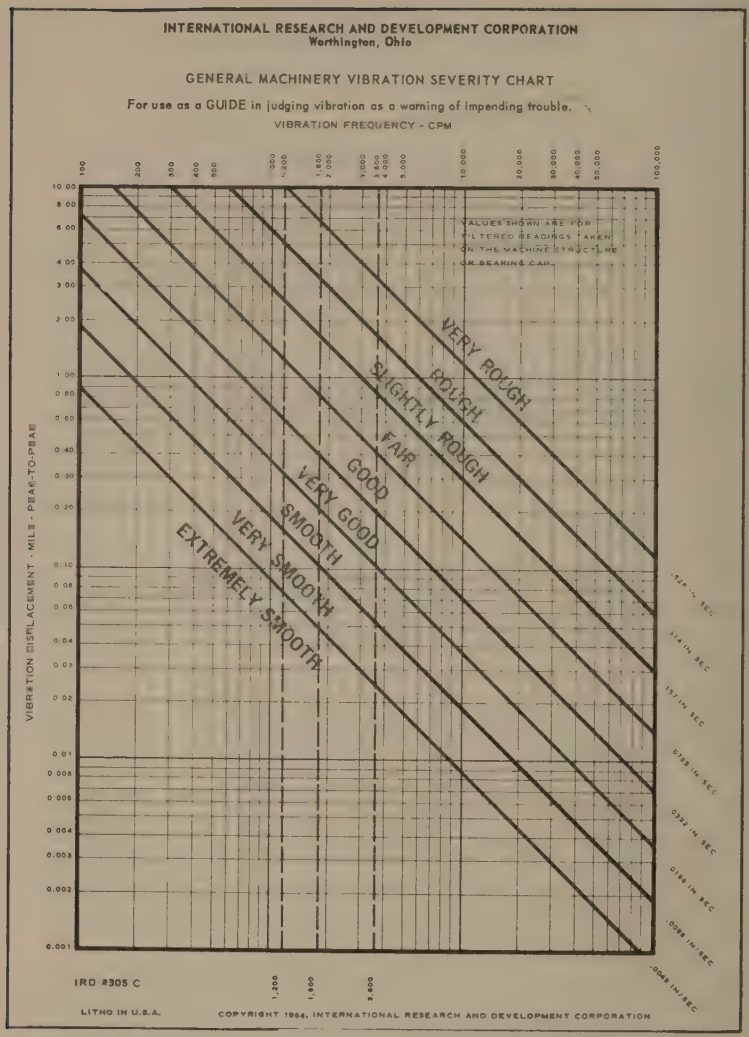
INTERNATIONAL RESEARCH AND DEVELOPMENT CORPORATION
Worthington, Ohio
GENERAL MACHINERY VIBRATION SEVERITY CHART
For use as a GUIDE in judging vibration as a warning of impending trouble.
VIBRATION FREQUENCY - CPM
VALUES SHOWN ARE FOR FILTERED READINGS TAKEN ON THE MACHINE STRUCTURE OR BEARING CAP.
VERY ROUGH
ROUGH
SLIGHTLY ROUGH
FAIR
GOOD
VERY GOOD
SMOOTH
VERY SMOOTH
EXTREMELY SMOOTH
VIBRATION DISPLACEMENT - MILS - PEAK-TO-PEAK
IRD #305 C
LITHO IN U.S.A.
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Figure 8. Vibration Severity Chart

Final Assembly Testing

Final vibration checks of finished products and assemblies before shipment assures compliance with production quality standards and customer satisfaction. New or overhauled machines can be checked for troubles due to faulty installation.

Field Maintenance of the IRD Model 320 Vibration Selector should be limited to malfunctions which can be located and corrected without the use of electronic test equipment.

Simple test and correction procedures are provided in the Operation Tests. These will assist the operator in determining when an easily-corrected malfunction has occurred. If these tests are performed and the operator or technician determines that the electronic portion of the Vibration Selector is inoperative, the Vibration Selector, pickup and cable should be returned to the factory for repair and calibration. If local qualified personnel with the proper test and calibration equipment are available to repair the instrument, additional maintenance and calibration instructions are available and may be requested from IRD.

Operation Tests

These tests are provided to help the operator determine if all segments of the Vibration Selector are performing their proper function after preparing the instrument for operation.

Battery Test

A battery test switch is provided on the rear panel of the instrument. The FILTER SELECTOR switch must be in the OUT position during the battery test. Good batteries indicate .9 or above on meter scale (the upper scale only is used for battery test). Weak batteries in Group 2 are to be expected after 200 hours of normal intermittent use (750 hours for Group 1). Observe the polarity of all batteries. There are two battery packs in the Model 320. These are designated "Group 1" and "Group 2". Each pack is made up of two (2) 8.1 volt cells. Both cells within a given group should be replaced at the same time, unless only one can be shown to be bad by substitution of a good bat-

tery. In general it is better to replace both at the same time. Gain access to batteries by turning the fastener on the rear panel 1/4 turn to left and pulling out batteries on hinged panel. See Figure 9.

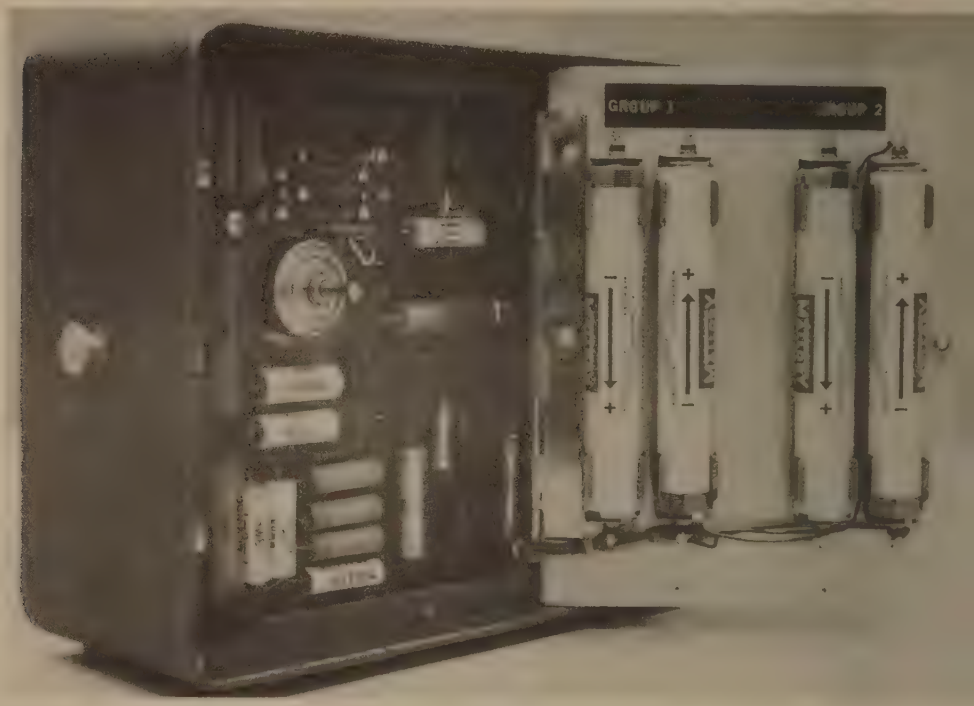


Figure 9. Instrument Batteries

QUANTITY	REPLACEMENT BATTERIES
(4) 8.1 Volt	Mallory TR-136R Eveready E136N Burgess H136R

Exact equivalents of these batteries from other manufacturers can be used. Care must be used in battery replacement so that interconnecting cables inside the instrument are not disturbed. When replacing batteries be sure to arrange polarity as shown in Figure 9, that is, positive ends to red terminals.

Pickup Cable and Meter Circuit Test

This test will permit the operator to determine if the pickup cable and meter circuit are functioning. For these tests, the instrument is prepared for normal operation and the controls are adjusted as follows:

AMPLITUDE RANGE SELECTOR: The least sensitive full scale position
FILTER SELECTOR: The OUT position (this turns the instrument on.)
RANGE: Inoperative
FREQUENCY TUNING: Inoperative
DISP-VEL SWITCH: DISP position

Grasp the pickup in the hand and shake it back and forth. A large amount of movement is not necessary - a short, fast shake will give better results. The AMPLITUDE meter should register more than full scale.

Filter Operation Test

This test will indicate if the filter is working on the 1500 to 5000 cycle per minute range. The satisfactory completion of this test would usually indicate that the filter will also work on the other ranges. Begin this test with the controls in the same position as the preceding test. Disconnect the pickup from the pickup cable and insert the bare end of a piece of insulated wire, which is several feet long, into the B contact of the pickup cable.

Slowly turn the AMPLITUDE RANGE SELECTOR control clockwise until a substantial meter reading is obtained. Note the meter reading.

Turn the SELECTOR to the IN position and the RANGE to the 1500-5000 CPM position. Turn the FILTER TUNING dial to approximately 3600 CPM and tune for the largest meter reading. This reading should be approximately the same as that noted above.

Troubleshooting Chart

The following chart is provided to aid the operator in locating the source of trouble in a malfunctioning Vibration Selector without the use of electronic test equipment. The troubles are therefore limited to simple items which are readily observed.

1. Amplitude meter indicates little or no response from pickup.

    a) Check pickup cable connections.
    b) Try AMPLITUDE RANGE SELECTOR switch on lower range.
    c) Test Vibration Selector for malfunction. With AMPLITUDE RANGE SELECTOR switch on .1 mil or 3 microns range and FILTER SELECTOR at OUT position touch right hand pin of PICKUP input with screwdriver. Any meter reading indicates the unit is operating.
    d) Test pickup cable. With pickup cable connected to Vibration Selector and the same setup as (c) insert the bare end of a wire several inches long into the "B" contact of the free end of the cable. Any reading on the AMPLITUDE METER will prove one half the cable is operative. With the bare wire still in the "B" contact, place the other end of the bare wire in the "A" contact. The meter should read zero. This tests the other half of the cable. Repair or replace if defective.
    e) Test pickup. With the same setup as (d) except the AMPLITUDE RANGE SELECTOR on 100 or 3000, shake pickup back and forth. Meter should indicate full scale or more. If no reading is noted, return pickup for repairs.

MODEL 320 PARTS LIST

Circuit Symbol	Description	Part No.
R1, R32	68K ohms 1/2W 1%	1566
R2	22K ohms 1/2W 1%	1563
R3	6.8K ohms 1/2W 1%	1555
R4	2.2K ohms 1/2W 1%	1551
R5	680 ohms 1/2W 1%	1545
R6	220 ohms 1/2W 1%	1544
R7	100 ohms 1/2W 1%	1543
R8, R26	5.6M ohms 1/2W 5%	3527
R9	10K ohms WW Pot	4821
R10, R35, R37	150K ohms 1/2W 1%	3491
R11, R18	56K ohms 1/2W 5%	3528
R12, R13, R16, R19, R21, R27	10K ohms 1/2W 5%	1596
R14, R17	2.2K ohms 1/2W 5%	1591
R15	1.8M ohms 1/2W 5%	1616
R20, R22	1.8K ohms 1/2W 5%	1590
R23	33K ohms 1/2W 5%	1600
R24	12K ohms 1/2W 5%	2999
R28	390K ohms 1/2W 5%	3108
R29	22K ohms 1/2W 5%	1598
R30	27K ohms 1/2W 5%	1599
R31	1.5K ohms 1/2W 5%	1589
R33	320K ohms 1/2W 1%	4822
R34	3.3K ohms 1/2W 1%	3003
R36, R47	91K ohms 1/2W 1%	1568
R38	2.7K ohms 1/2W 1%	3616
R39	2.0M ohms Special Pot	4886
R40, R41, R42, R46	1K ohms WW Pot	4724
R43	3.3 K ohms 1/2W 5%	1592
R44	1.2K ohms 1/2W 5%	1588
R45	470K ohms 1/2W 5%	1611
R48	2K ohms WW Pot	4517
R49, R25	1K ohms 1/2W 5%	1587

Circuit Symbol	Description	Part No.
C1, C2	3MF 12V	3530
C3, C26, C28	0.1MFD 50V 1%	3506
C4	500MFD 3V	3531
C5	.68MF 25V	5007
C6, C11	25MFD 12V	3532
C7, C9, C29	200MFD 15V	3533
C8	2000MFD 6V	4578
C10	5MF 6V NP	3490
C12, C13	5MFD 25V	3537
C14, C25	1000MFD 15V	3615
C15, C20	3MFD 50V 1%	3500
C16, C19	1MFD 50V 1%	3501
C17	.3MFD 50V 1%	3503
C21	.0243MFD 50V 1%	3502
C22	.0105MFD 50V 1%	3504
C23	.00243MFD 50V 1%	3505
C24	5MFD 50V	3534
C27	.00105MFD 50V 1%	4752
Q1, Q6	2N1711	3893
Q2	21N1711 Selected	9190
Q3, Q4, Q5, Q7	2N3391	4826
D1, D2	IN5239A	8457
D3	IN3019B Zener 9.1V	3567
Batteries (4)	8.1V Mercury	4600
Meter	50 Microamp	11998
Knob	Filter Tuning	4612
Knob	All Others	4615
Feet		3358
O-Ring	Dial Drive	4281
Switch	Filter Range (5-Pole, 4-Pos)	4723
Switch	Selector (4-Pole, 3-Pos)	4819
Switch	Amplitude Range (1-Pole, 7-Pos)	
	Without Resistors	4818
	With Resistors	4874
Switch	Batt Test (2-Pole, 3-Pos)	4820
Switch	Disp-Vel (1-Pole, 2-Pos)	4855

Accessories

Straight Probe	1103
4' Pickup Cable	2482
Carrying Case	3489
Carrying Case Strap	3829
Model 544 Vibration Pickup	4526
Operation Manual	4104

AUTHORIZED SERVICE DEPOTS

USA

IRD MECHANALYSIS, INC.
6150 Huntley Road
Columbus, Ohio 43229
Phone: 614/885-5376
Telex: 24-5318

IRD MECHANALYSIS, INC.
Suite A2
221 South Chester Pike
Glenolden, Penna. 19036
Phone: 215/461-7060

IRD MECHANALYSIS, INC.
Building C3
6001 Gulf Freeway
Houston, Texas 77023
Phone: 713/921-2145

IRD MECHANALYSIS, INC.
Suite 4
3377 Mt. Diablo Boulevard
Lafayette (San Francisco)
California 94549
Phone: 415/283-2065

CANADA

IRD MECHANALYSIS LIMITED
333 Barton Street East
Stoney Creek, (Hamilton)
Ontario, Canada L8E 2L1
Phone: 416/662-7577
Telex: 061-8453

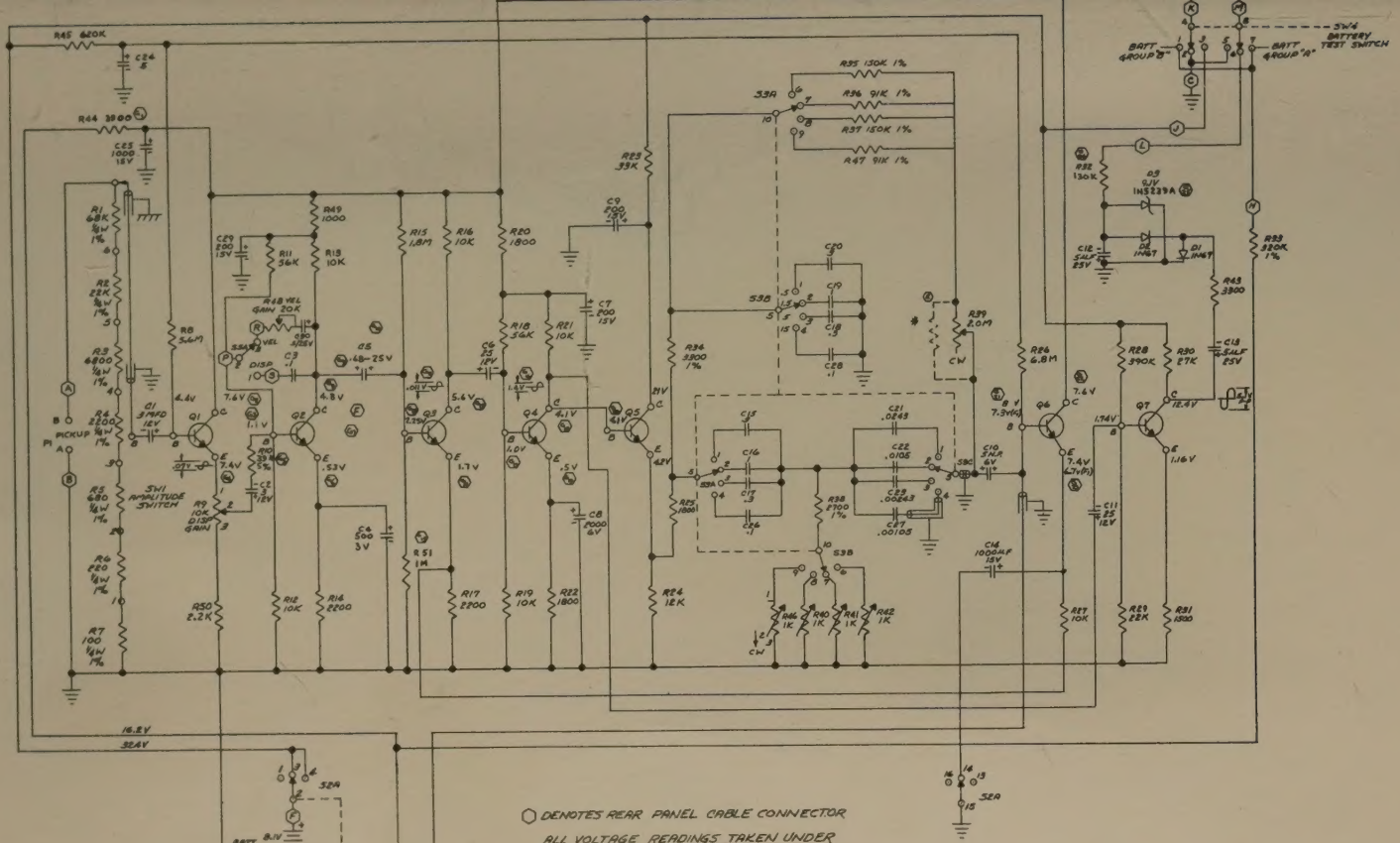
IRD MECHANALYSIS LIMITED
Room 203
524 17 Avenue, S. W.
Calgary, Alberta
Canada T2S OB2
Phone: 403/264-4130
Telex: 03-824680

UNITED KINGDOM

IRD MECHANALYSIS (UK) LIMITED
Bumpers Lane
Sealand Industrial Estate
Chester, United Kingdom CH1 4LT
Phone: Chester 44/244/374914-5
Chester 44/244/317557-8
Telex: 851-617034 IRD MECH G

WESTERN EUROPE

IRD MECHANALYSIS, S.A.
Avenue Winston Churchill 98
B1180 Brussels, Belgium
Phone: 32/2/344.70.58
32/2/344.72.18
Telex: 846-61256 IRD BRU B



⬡ DENOTES REAR PANEL CABLE CONNECTOR

ALL VOLTAGE READINGS TAKEN UNDER FOLLOWING CONDITIONS:
- INPUT SIGNAL 100 CPS 240 MV
- AMPLITUDE RANGE 5W 1.0
- DISP VEL 5W - DISP
- SELECTOR 5W "OUT" EXCEPT THOSE MARKED (F1) TAKEN WITH SELECTOR SW "IN" & FILTER PEAKED
- AC VOLTAGES ARE P-P MEASURED WITH OSCILLOSCOPE
- DC VOLTAGES ARE MEASURED WITH V.T.V.M. 11 MEG INPUT IMPEDANCE

ALL FIXED RESISTORS ARE HALF WATT 5% UNLESS NOTED
ALL RESISTOR VALUES ARE IN OHMS UNLESS NOTED
ALL CAPACITORS ARE 50 W.V.D.C. UNLESS NOTED
ALL CAPACITORS ARE IN M.F.D. UNLESS NOTED

Ⓚ Q1, Q2 AND Q6 - 2N1711
Q3, Q4, Q5 AND Q7 - 2N3391 Ⓟ Ⓢ
LAST RESISTOR R51 Ⓚ
LAST CAPACITOR C30
LAST DIODE D3 Ⓢ
LAST TRANSISTOR Q7
* PADDING RESISTOR USED ON SOME MODELS